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Correlation Between Transmissivity and Basal Area in Arizona Ponderosa Pine Forests[1]

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Transmissivity (portion of insolation incident upon forest canopy that is transmitted through the overstory to the snow surface) was empirically related to stand basal area of sample plots by a logarithmic transformation. Seasonal variation was not statistically significant.

Keywords: Basal area, insolation, transmissivity, *Pinus ponderosa*.

Introduction

Snowmelt is a major source of runoff to the reservoir system in central Arizona. More than 68 percent of the flow to the reservoir system may originate as snowmelt during the spring runoff period (Warskow 1971). Because snow contributes such a large proportion of the surface water in the State, it warrants intensive investigation and management.

Snowmelt is a dynamic process involving different energy transfers, and as such, must be assessed with changes in time. As a consequence, prediction of snowmelt is complex and involves the identification of many variables which themselves are continually changing. Primary sources of energy to melt snow are short- and long-wave radiation. Short-wave radiation incident upon the forest canopy can be affected by percent transmittance of insolation through the forest overstory, albedo of the snowpack, snowpack density, and depth, slope, and aspect.

Description of Study

Transmissivity is the primary variable controlling the amount of short- and long-wave radiation available at a snowpack's surface. Thus, if solar radiation measurements are to be used as the energy source for snowmelt prediction, a relationship between percent transmittance (that portion of insolation incident upon the forest canopy that is transmitted through the overstory to the snowpack) and a readily measured forest attribute must be identified. To this end, a study was initiated at Campbell Blue in east-central Arizona.

Study Area

The Campbell Blue area is located 7 miles south of Alpine on the Apache-Sitgreaves National Forest. A predominantly ponderosa pine forest, the site supports diverse forest cover densities ranging from open parks to dense stands. With a mean elevation of 8,000 feet, this gently rolling study area contains few slopes in excess of 15 percent, providing a suitable site for studying solar radiation transmissivity.

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Methodology

The sample design consisted of three clusters containing five sample points per cluster forming a one-fifth-acre plot. Each cluster was designed in the shape of a diamond, with one point at the four corners of the diamond and the fifth point in the center 50 feet from each corner point. Because each point in a cluster represented a different forest condition, it could be treated as a discrete sampling point. This produced 15 different forest conditions in the sample, within the size classes present (large poles to small sawtimber).

Six solar pyranometers were used in the study: five were used to sample transmissivity, while the sixth, located in Alpine atop a mobile home, served as a control. Thus only one cluster was sampled per day. The sensors were rotated randomly every day among sample points.

Before sunrise of a sampling day, the sensors were mounted and leveled atop 3-foot wood stands located at each sampling point, then connected to digital integrators (Thompson and Ozment 1972) and hourly readings taken from sunrise to sunset. Only sunrise and sunset readings were recorded on days with extensive cloud cover. A total of 16 days of data were collected during periods of measurement, one in March and the second in June.

Forest overstory characteristics influence the amount of insolation transmitted through the overstory. Therefore, a measure of forest attributes might be used to index the amount of radiation incident upon the snowpack. Basal area and stem density were measured at each sample point by point-sampling techniques.

After field data were collected, the sensors were calibrated to standardize all records. Shading cloths of various transparencies were used to expose each sensor to different energy fluxes. One sensor was arbitrarily chosen as standard, and the other five were correlated with it by means of regression equations.

Once each sensor was calibrated to a standard scale, the next step was to transform all data to that same scale. It was assumed that radiation recorded by each sensor on clear days approximated a cosine curve. It was further assumed that this cosine curve could be approximated by two linear segments, one rising and one falling, to form a triangle. With these two assumptions, it was then possible to calculate an average langley value for the entire day, substitute this value into the corresponding regression equation, and arrive at the total standardized langleys for the particular sensor. This procedure was followed for all sensors on clear days. For cloudy days, the procedure was duplicated with the exception that only that part of the day with no cloud cover was considered as contributing significant flux differences between the opening and forested conditions.

The standardized daily insolations were then plotted and regressed against the forest attributes to establish any significance between variables.

Results and Discussion

Basal area and stem density proved significant as empirical indexes of transmissivity. However, the correlation coefficient of stem density versus transmissivity was only 0.50 compared with 0.83 for basal area; therefore, basal area was chosen as the predictor of transmissivity.

Since no significant difference existed between March and June transmissivities grouped by basal area, all data were combined in a plot of transmissivity values against basal area (fig. 1).

Transmissivity values on cloudless days were statistically identical with those values obtained on cloud-free portions of partially cloudy days. Transmissivity averages ranged between 40 and 55 percent on cloudy days, independent of basal area or season.

Previous work has indicated nonlinear relationships between transmissivity and forest attributes (Muller 1971, Reifsnyder and Lull 1965). An inspection of figure 1 suggests that a logarithmic transformation might be used to develop a regression equation. With such a transformation, the following equation, with a correlation coefficient of 0.794, resulted:

$$\log(TR) = 2.144 - 0.229 \log BA$$

where

TR = transmissivity in percent, and
BA = basal area in ft^2 per acre.

It should be emphasized that the range of basal area values was 25 ft^2 per acre to 125 ft^2 per acre within the size classes present, and that extrapolation beyond those limits might not be justified. However, on the lower end we know that zero basal area would be 100 percent transmissivity.

Conclusions

Because the primary concern in this study was the determination of average transmissivities during the snowmelt season, no attempt was made to assess diurnal variation in this factor. Measurements made in March and June were not significantly different; thus, a combined equation for estimating the snowmelt-season transmissivity was possible.

The relationship between basal area and transmissivity proved to be curvilinear; therefore, a logarithmic transformation was used in the final regression analyses.

Cloudy-day transmissivities were not related to basal area or season (sun angle).

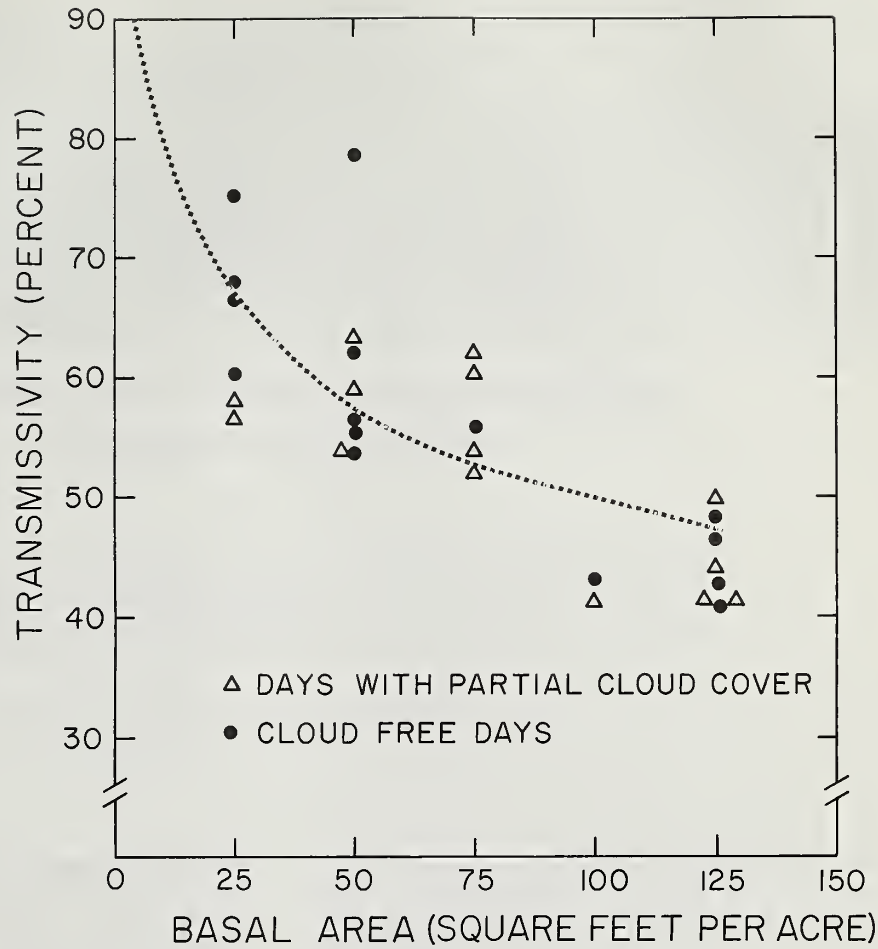

Figure 1.—Correlation of transmissivity against basal area at the five levels of basal area represented by the sample plots. The regression is obviously curvilinear because 100, 0 is a known point.

Results of this study suggest that correlation between transmissivity and basal area—an easily measured forest stand parameter—may be used to estimate the energy source for snowmelt prediction in Arizona's ponderosa pine forests.

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